

## Summary of King Mackerel Tagging in the Southeastern USA: Mark-Recapture Techniques and Factors Influencing Tag Returns

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**Abstract.**—Between 1975 and 1988, biologists with the Florida Department of Natural Resources and the National Marine Fisheries Service tagged more than 26,000 king mackerel *Scomberomorus cavalla* in the Atlantic Ocean and Gulf of Mexico, from North Carolina to Yucatan, Mexico. Various types of tags were used, but internal anchor tags were most effective and provided over 1,400 recoveries. Most fish were caught for tagging by trolling with hook and line; tagging the fish in V-shaped tagging cradles aboard vessels proved most efficient. Overall operational costs have increased markedly during these studies mainly due to the increased cost of purchasing fish for tagging. Tagging studies in the 1970s provided the basis for establishing separate management units of king mackerel in the Atlantic Ocean and Gulf of Mexico, and subsequent tagging studies contributed to further definition of fish in the Gulf of Mexico into distinct eastern and western groups. Increased fishery regulation has resulted in decreased tag reporting because fishermen express their resentment of the controls by not reporting tags. The most effective incentive for fishermen to return recovered tags is a high monetary reward.

King mackerel *Scomberomorus cavalla* is a coastal, pelagic scombrid that ranges from the Gulf of Maine to Rio de Janeiro, Brazil (Briggs 1958). The fish reach a maximum size of 173 cm fork length and 45 kg in weight (Collette and Nauen 1983), but most king mackerel taken commercially range between 60 and 90 cm (Trent et al. 1983). In 1985, commercial fishermen landed 2.4 million kg and recreational anglers landed 5.3 million kg of this fish (USNMFS 1986a, 1986b).

In the early 1960s, king mackerel was the species most desired by private boat anglers, and it was the staple of Florida's charter fleet (Moe 1963). At that time, a small troll fishery in southeast Florida was the only commercial fishery of any size for this species in the USA. With the advent of the power block in 1963 (Beaumariage 1973), gillnetting and aerial fish spotting increased yearly commercial landings to a high of over 4.7 million kg in 1974 (Gulf of Mexico and South Atlantic Fishery Management Council 1985). Since that time, stock assessments by National Marine Fisheries Service (NMFS) personnel have indicated that the Gulf of Mexico migratory group (those fish off southern Florida in the winter months) has declined due to overexploitation. Catch quotas were set in 1982 and were lowered in the ensuing years. In December 1987, catch quotas had been met for both commercial and recreational fisheries on the eastern zone of the Gulf

migratory group, and all but catch-and-release, recreational fishing for king mackerel stopped.

The first tagging of king mackerel took place in 1963 when 640 fish were tagged with spaghetti tags and 47 were tagged with internal anchor tags (Beaumariage 1964, 1969; Beaumariage and Wittich 1966; Moe 1966). Only six tagged fish were recovered and little migration information resulted. However, it generally was accepted by fishermen that, in Florida waters, these fish migrated northward in spring and southward in fall.

When landings of king mackerel peaked in 1975, a cooperative mark-recapture study was undertaken by the Florida Department of Natural Resources (FDNR) and the NMFS. Between 1975 and 1979, 17,042 king mackerel were tagged by biologists with these agencies and 1,171 tags were returned (Sutherland and Fable 1980; R. O. Williams and M. F. Godcharles, FDNR, unpublished 1984 report). Besides the accepted north-south migrations, Williams and Godcharles identified two stocks or migratory groups, a Gulf group and an Atlantic group. The ranges of the two groups roughly coincided with the boundaries of the Gulf of Mexico and the Atlantic coast of the southeastern USA, but the Gulf group extended into waters off southeast Florida in the winter months. All stock assessments and catch allocations for king mackerel since 1985 have been made separately for these two migratory groups.

Since 1980, tagging by the NMFS and various cooperating agencies has been aimed at more detailed discrimination of king mackerel stocks. Two hundred thirty-two tags have been returned from 9,122 king mackerel tagged since the end of the FDNR-NMFS cooperative study. Information from this tagging has helped divide the previously described Gulf group into eastern and western segments (Fable et al. 1987) and is providing more information on the Atlantic coast fish and the king mackerel moving into Mexican waters.

This report describes and discusses the mark-recapture methods used for king mackerel studies in the southeastern USA and Mexico and discusses factors influencing the tag returns.

### Methods

The earliest king mackerel tagging studies in the 1960s (Moe 1966), used spaghetti tags (Floy Tag and Manufacturing) because of successes with these tags reported by Wilson (1953) and Clemens (1961) who used them for tagging other large scombrids. All tags had a legend on them that advertised a reward and gave a return address. Fish were caught from small boats with commercial handline techniques and placed in a padded tagging trough. Moe (1966) stressed that speed was the most important factor for successful tagging of king mackerel and that a maximum limit of 40 s out of the water would ensure survival of this species.

When the FDNR-NMFS cooperative study began in 1975, FDNR biologists obtained fish for tagging in southern Florida by purchasing live king mackerel from commercial handline fishermen. Fish were brought aboard the boat by the fishermen, and the hook was pulled over a de-hooking bar and held upside down until the fish fell off into a box. With wet, gloved hands, the tagger lifted the fish into a padded tagging cradle and recorded its fork length. Fishermen were paid market price or slightly more for all tagged fish.

The FDNR biologists chose an internal anchor tag (Figures 1, 2) for use on king mackerel. Although 47 of these tags were used on king mackerel in 1964 and 1965 (Beaumariage and Wittich 1966; and Beaumariage 1969) and none were returned, Topp (1963) stressed this tag's permanence and nonirritating qualities. In 1968, 60 king mackerel were tagged with internal anchor tags, and four of the tags were returned (Williams and J. A. Huff, FDNR, unpublished 1976 report). When tagging began in the 1970s, the tags were

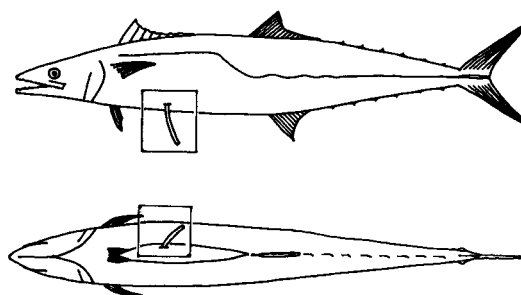


FIGURE 1.—Lateral and ventral views of king mackerel with placement of internal anchor tags indicated.

inserted by making a 6-10-mm incision in the anterior abdomen (Figure 1) with a scalpel, inserting the disk of the internal anchor tag by hand, and returning the fish to the water (Williams, FDNR, unpublished 1976 report).

National Marine Fisheries Service biologists tagged king mackerel where commercial handline fisheries for the species did not exist: in North Carolina, northwest Florida, and Texas (Sutherland and Fable 1980). Fish were caught by the taggers with a hook and line (either handline or rod and reel) and tagged with a single-barb dart tag (Figure 2). Sutherland and Fable (1980) reported that Fry and Roedel (1949) found a minimum of 23% mortality in chub (Pacific) mackerel *Scomber japonicus* tagged with a body cavity tag,

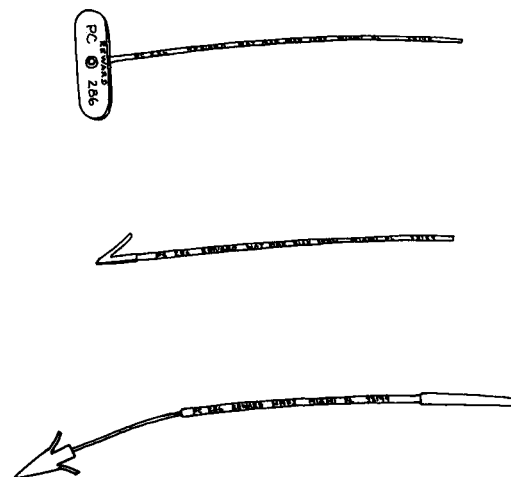


FIGURE 2.—Types of tags used on king mackerel: top, internal anchor tag; middle, single-barb dart tag; bottom, double-barb dart tag.

and that Yamashita and Waldron (1958) reported favorable results with single-barb dart tags.

About 1,100 fish were tagged initially in 1975 in the water alongside the boat by inserting the single-barb dart tag in the dorsal musculature with a tagging needle on a pole. The leader was then cut as close to the hooks as possible. Later, fish were brought aboard the boat and held in a V-shaped tagging cradle or on a wet deck so hooks could be removed, fork length could be measured, and the tag could be inserted more carefully (Sutherland and Fable 1980). Like the internal anchor tags, the single-barb dart tags had a legend indicating that a reward was offered and the address to which the tag should be returned.

Throughout the FDNR-NMFS cooperative study, a reward was offered that varied from a minimum of \$1 (raised to \$5 in 1976) to a maximum of \$25, depending on the serial number of the tag. Fishermen were familiarized with the mark-recapture work by various methods, including posters at marinas and fish dealers, newspaper articles and press releases, and personal contacts.

In 1983, when king mackerel tagging resumed after the conclusion of the FDNR-NMFS study from 1975 to 1979, it was in response to a new hook-and-line fishery developing in Louisiana. Internal anchor tags were used exclusively, and fish were caught on handlines from government boats or were purchased live from commercial handline fishermen. As reported by Fable et al. (1987), fish initially were held down on deck to immobilize them for tagging. Later, on commercial vessels, fish were unhooked over a dehooking bar and tagged in a padded tagging cradle. Rewards were set uniformly at \$10 for each returned tag and remained at that amount through 1985. In 1986, a yearly \$1,000 drawing from returned tags was initiated as an added incentive to anglers.

From 1983 through 1987, king mackerel mark-recapture work took place from North Carolina to Mexico. The initiation of tagging in a given area depended on the need for data from that region (usually emphasized by a fishery management council request), the accessibility of adequate numbers of king mackerel, and adequate funding for the work.

In Louisiana, on the east coast of Florida, and to some extent in North Carolina, most tagging was done from commercial vessels. The limiting factor for the number of fish tagged was the cost of the fish. In the 10-year period from 1975 to 1985, the ex-vessel price for king mackerel increased from around US\$0.40 per pound to \$1.50

or more. This often meant that each tagged fish cost \$20.

Encouraging recreational anglers to tag and release their unwanted king mackerel catch has been the most economical approach to mackerel tagging. This method has been used with some success in Texas and North Carolina, but recreational anglers find it difficult to handle king mackerel for insertion of internal anchor tags. In response to this problem, a double-barb dart tag, originally developed for small bluefin tuna *Thunnus thunnus* by E. Prince (NMFS, Miami), was adapted for king mackerel (Figure 2). This tag was used for tagging king mackerel in Panama City, Florida, in 1986, and has been used by anglers participating in the cooperative game-fish tagging program at the NMFS Southeast Fisheries Center in Miami, Florida.

The most challenging mark-recapture work has been done in Mexico by biologists from the Mote Marine Laboratory under contract to the National Marine Fisheries Service and the Instituto Nacional de Pesca, the Mexican fisheries agency. Hook-and-line trolling methods have been used successfully, but vessels are usually small, open outboard launches and frequently are idled by inclement weather. The most effective method for obtaining king mackerel in Mexican waters has been the use of trap nets (termed *almadrabas*) found in the Veracruz area. These nets were fished twice a day by the local fishermen. Live king mackerel were dipnetted or simply picked up out of the net when it was raised. Often, 30 fish or more were tagged in as many minutes. The fish were brought aboard launches, placed in a tagging cradle, measured, tagged, and released.

### Results and Discussion

The FDNR-NMFS tagging study conducted between 1975 and 1979 resulted in 17,042 tagged king mackerel and 1,171 returned tags. Internal anchor tags used by FDNR personnel yielded a much higher return rate (8.1%) than the single-barb dart tags (1.1%) used by NMFS biologists (Table 1). In the initial year of the NMFS tagging study (1975), over 1,100 king mackerel were tagged in the waters off northwestern Florida, and no tags were returned (Sutherland and Fable 1980). After that, fish were brought aboard the boat and tagged, and returns resulted, but the return rate never approached that achieved by FDNR biologists using internal anchor tags.

In a tag-retention experiment (Williams, FDNR, unpublished 1978 report), 1,354 king

TABLE 1.—Numbers of king mackerel tagged, the number returned, and return rates from mark-recapture studies during the 1970s and 1980s.

Tagging years	Organization <sup>a</sup> or area	Number of fish		Return rate (%)
		Tagged	Returned	
1975–1979	FDNR	14,137	1,139	8.1
1975–1979	NMFS	2,905	32	1.1
1983–1987	All areas combined	9,122	232	2.5
1983–1987	North Carolina	2,196	32	1.5
1985–1986	NE Florida	891	31	3.5
1987	SE Florida	1,005	40	4.0
1983–1987	NW Florida	1,174	32	2.7
1985–1987	Louisiana	2,362	59	2.5
1985–1987	Texas	341	8	2.3
1984–1987	Mexico	1,153	30	2.6

<sup>a</sup>FDNR = Florida Department of Natural Resources; NMFS = National Marine Fisheries Service.

mackerel were marked in equal numbers with either an internal anchor tag or a single-barb dart tag. There was little difference in return rates for the first 180 d; however, no dart tags were recovered after that time. After 480 d, 39 internal anchor tags and only 14 dart tags had been returned. Both Williams (unpublished) and Sutherland and Fable (1980) reported that failure (i.e., loss) of the single-barb dart tag may have been the cause of this difference. Evidence indicated that the plastic streamer detached from the nylon dart after 3–4 months due to breakdown of the adhesive connecting them (Bruger 1981).

Adding to this problem, at least during the initial tagging of 1,100 king mackerel in northwest Florida, fish were tagged in the water and hooks were left in the fishes's mouths (Sutherland and Fable 1980). In Texas that same year (1975), 282 king mackerel were tagged with the same type of single-barb dart tag, but they were brought aboard the boat and the hooks were removed. Three returns resulted from these 282 tagged fish. Sutherland and Fable (1980) believed that failure to implant the tag properly in moving fish, as well as dangling hooks contributed to the poor results.

In the FDNR–NMFS mark-recapture study in the 1970s, the two agencies used different methods and different tags, and the FDNR achieved an excellent return rate. When the FDNR returns were combined with returns from tagging by NMFS in the Gulf of Mexico, a great deal of valuable migration information resulted. No extensive comparative tag testing took place (except that each group used a different type of tag), and tag retention and tagging mortality were not measured.

When tagging resumed in the 1980s, internal anchor tags were used almost exclusively because of the 8.1% return rate and the successes reported

by Williams and Godcharles (unpublished). From 1980 to 1988, NMFS and cooperating agencies tagged 9,122 more king mackerel and received 232 tag returns (a 2.5% return rate). However, new influences affected tag return rates after 1982. In the 1970s, king mackerel tagging was new to the fishermen, and most welcomed the opportunity to participate, both by tagging fish and returning tags, because they had observed the species' movements for years and wanted more information about these movements. At that time, fishery allocations and quotas did not exist and landings were higher than ever before, although high catches by large gill-net vessels were starting to worry some fishermen. In the following years, catches varied greatly, and quarrels between fishermen with different gear types broke out. By 1982, the South Atlantic and Gulf of Mexico Fishery Management Councils were exerting influence on fishermen, and in May of 1983, the commercial hook-and-line fishery was closed for about 2 months when the quota was reached. By 1987, combined recreational and commercial catch quotas for both the Atlantic Ocean and Gulf of Mexico migratory groups for the entire south-eastern USA were reduced to 5.4 million kg. In the winters of 1985–1987, the commercial fishery in south Florida met its quota each year. The recreational fishery also was closed in 1987. Most fishermen resent these closures, and many react by not reporting tag recoveries.

The nonreporting of tag recoveries is evident in Table 1, where the overall return rate in the 1980s was 2.5% versus 8.1% in the 1970s for internal anchor tags. Some of this difference is probably due to tagging in areas where an intense commercial fishery did not exist, such as northwestern Florida and Texas, but even when tagging took place in the midst of heavy fishing pressure, such

TABLE 2.—Results of tests to compare the effectiveness of internal anchor tags (IAT) and double-barb dart tags (DT) for king mackerel in northwest Florida.

Number and type of tags	N	Number of tags per fish	Number of fish returned	Number of tags returned		Number of tags lost	
				IAT	DT	IAT	DT
1 IAT	139	1	6	6		0	
2 IATs	139	2	5	8		2	
1 DT	139	1			1		0
1 IAT + 1 DT	139	2	3	3	1	0	2
Total	556		15	17	2	2	2

as in northeastern and southeastern Florida, return rates were less than half of the return rate for the 1970s.

Nonreporting of internal anchor tags has been discussed by Matlock (1981) and Green et al. (1983). They found that only 28–29% of tags implanted in sciaenids landed in Texas waters were reported. The most frequent reason for not reporting a tag, according to the anglers, was their failure to find it. These authors suggested that reporting might be increased if the tag were more visible and larger monetary rewards were offered. (Their rewards varied between \$1 and \$25.)

Little more can be done to make tags more visible (NMFS biologists have used international orange tags since 1983), but rewards could make a substantial difference. In the 1970s, rewards varied from a minimum of \$5 to a maximum of \$25. In the 1980s, the reward was set at \$10, and a \$1,000 drawing from returned tags was held each year in 1986 and 1987. In the 1970s, king mackerel were purchased from commercial fishermen for about \$5 each. In the mid-1980s, the tagging of about 1,900 king mackerel on the east coast of Florida cost over \$36,000 for the fish purchases alone (about \$19 each). Seventy-one of these fish were recovered, and \$710 was spent on rewards besides the \$1,000 spent each year for the drawing. Thus, less than \$3,000 was spent in monetary rewards to get returns on over \$36,000 worth of fish. Most fishermen can afford to give up a \$10 reward, but if the reward were raised to \$50 or more, few fishermen would ignore or discard tags. If the reward had been \$50, the total spent on rewards (at the same return rate) would still have been under \$6,000.

Other mark-recapture studies at the Southeast Fisheries Center (billfish tagging, redfish tagging) have had \$5 rewards, and raising the reward on king mackerel tags past \$10 has not been authorized. In one instance, however, a substantial reward (\$100) was offered for the return of tetra-

cycline-tagged king mackerel in 1983 and 1984. Posters advertising this were distributed, and 216 fish were marked and released. Seventeen tags were returned. This represented a 7.9% return rate—a rate close to that realized by Williams and Godcharles (unpublished) in the 1970s. This indicated that a high reward will induce more fishermen to return tags.

Most of the mark-recapture work done in the 1980s was not designed for experimentation with various tagging techniques or testing of different tag types. When fish were purchased for \$15 to \$20 each aboard commercial vessels, the tagging technique and tag type that had proven successful in the past was employed. In waters adjacent to the NMFS's laboratory in Panama City, Florida, however, alternative marking techniques could be tested. Because king mackerel can be caught in fairly large numbers in the summer months and are found relatively close to shore, and because sea conditions allow outboard boats to be employed by NMFS personnel to catch the fish, my colleagues and I did some tag testing and double tagging in 1986 and 1987.

A double-barb dart tag (Figure 2) was developed for king mackerel from the design by Prince (unpublished) for bluefin tuna. This tag was tested in 1986 by comparing it to the internal anchor tag. Five hundred fifty-six king mackerel were tagged with either one internal anchor, two internal anchors, one double-barb dart, or one double-barb dart and one internal anchor. In all, 278 double-barb dart tags and 556 internal anchor tags were used. Seventeen internal anchor tags were returned and two had fallen out, whereas two double-barb dart tags were returned and two had fallen out (Table 2). Returns were greatest when fish were tagged with one internal anchor tag and were least with one dart tag. The double-barb dart tags have been in use for king mackerel since 1986 in the cooperative game-fish tagging program centered at the NMFS's Miami laboratory. Alto-

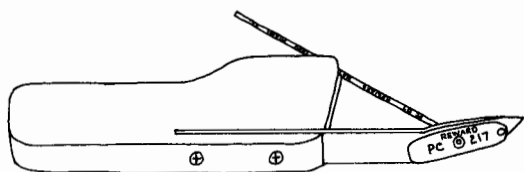


FIGURE 3.—Internal anchor tag inserter. (Designed by L. Trent.)

gether, 208 king mackerel had been tagged in this program by 1988, and two tags have been recovered.

The double-barb dart tag was somewhat less effective than the internal anchor for tagging king mackerel during the limited 1986 testing, but the difficulties encountered during insertion of anchor tags have limited their use by recreational anglers. A stainless steel knife-like inserter designed by L. Trent (NMFS, Panama City, Florida) holds an appropriately modified internal anchor tag while it slices under the abdominal skin and flesh of a king mackerel (Figure 3). This device may allow an untrained tagger to insert these tags easily. These inserters are being used on sciaenids in North Carolina and were being studied by Floy Tag and Manufacturing for possible commercial production.

In 1987, 402 king mackerel taken in Panama City all were double-tagged with internal anchor tags. As of May 1, 1988, only one fish had been recovered. The return rate had declined to almost zero, largely due to a closed commercial fishery and to zero bag limits in the recreational fishery of south Florida, where Gulf king mackerel winter. When these fisheries re-open in mid-1988, some tag returns are anticipated despite the fishermen's resentment of fishery management practices.

### Conclusions

There are several lessons to be learned from king mackerel mark-recapture studies that have been done in the southeastern USA. Most important is the need for comparative tag testing (i.e., tag retention and tagging mortality determinations) before long-term, expensive mark-recapture programs begin. Such testing is not easily or inexpensively done on a scombrid such as king mackerel, but the time and money would be well spent.

Once tagged fish are freed, maximum effort should be used to recover tags. Although anglers accepted tagging in the 1970s and monetary rewards seemed adequate to gain their cooperation, fisheries regulations imposed in the 1980s resulted

in resentment of governmental interference by anglers, and they became reluctant to return tags. To counteract this resentment, two measures seem appropriate. The first is to increase public awareness of the purpose of the regulations. Although the numerous fishermen interviewed seemed to understand the purpose of the regulations, a second measure—a high monetary reward for returned tags—probably would be more effective. When the tagged fish cost up to \$20 each, the minimum reward should be \$50 when return rates are well under 10%.

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